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Auditory Processing in Dyslexia: Middle Latency Event-Related Potentials and Temporal Sequencing

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ABSTRACT

Behavioral and electrophysiological processing of sequential tones was investigated in reading delayed (RD) and non-reading delayed (NRD) children matched on intelligence and reading level. NRD children performed consistently better on sequencing of tonal patterns ($F=5.78$, $p<.03$). Middle latency event-related potentials (MERPs) from the RD group indicated reduced latency of the Na waveform generated by the second of two sequential stimuli at short compared to longer inter-stimulus intervals ($t=4.66$, $p<.001$). The latency of this peak was correlated to performance on the sequencing task ($r=.45$, $p<.006$). These results were interpreted as indicative of a lack of normal inhibition by the RD group of the second sequentially presented tone.

Auditory Processing in Dyslexia: Middle Latency Event-Related Potentials and Temporal Sequencing

Dyslexia has been reported to involve an impaired ability to process two rapidly occurring, successively presented auditory stimuli. Tobey et al. (1979) found reading delayed children to be impaired in their ability to correctly identify consonant vowel syllables with inter-stimulus intervals as long as 150 milliseconds. Tallal (1980) found that as the inter-stimulus intervals decreased, reading impaired children made more errors than the controls in a sequencing task. Tallal et al. (1981) reported that language impaired subjects made almost twice as many correct order errors on the average as did the control subjects, and required on average a 300 milliseconds inter-stimulus interval between two 75 milliseconds tones in order to respond correctly, whereas normal children required an 8 milliseconds inter-stimulus interval.

A dependable method to study the processing of temporal or basic sensory information is the use of event-related potentials. By the presentation of two tones of different frequencies and recording the Middle Latency Event-Related Potentials (MERP) to each category of tones, the processing mechanism involved in temporal organization can be analyzed. Impairment in activation of the nonspecific sensory arousal system and thus the related limits to rapid auditory processing will cause information from temporally close sounds to be lost.

METHOD

Subjects. 15 Non-Reading Delayed (NRD) and 15 Reading Delayed (RD) children, matched on reading level and IQ, served as subjects. For the RD group mean (SD) age was 11.2 (.64), while for the NRD group it was 8.4 (.59). For the NRD group mean IQ was 104.8, while for the RD group it was 104.5. The mean reading grade levels for the NRD and RD groups were 2.8 and 2.7, respectively.

Materials. The Word Identification subtest from the Woodcock Reading Mastery Test was used to screen for reading aptitude. Intellectual estimates were obtained through the administration of the Vocabulary and Block Design subtests from the WISC-R.

The behavioral task was performed on a Macintosh SE computer, using a pitch discrimination program (Chute, 1988) to generate the sequences.

Two Hewlett Packard Model 200 ABR Audio Oscillators, and a Hewlett Packard Attenuators 350 C Attenuator Set was used to generate the auditory stimuli, which was delivered through a set of Telephonics TDH-49P headphones.

MERPs were collected using a microcomputer interface system, with Grass Model P511-K Preamplifiers, and a Metrabyte Dash 16 A/D board.

Procedure. NRD subjects were obtained through teacher nomination and a review of school records, to identify children who scored between the 35th and 65th percentile on standardized measures of reading (overall score). Teachers of learning disabled classes were asked to identify children in their classrooms with average

intelligence, who were reading at least two years below their grade level. School records were examined to select from this group students with either Verbal or Performance IQ scores over 90. These children were individually tested on the Word Identification subtest of the Woodcock Reading Mastery Test. The subtests from the WISC-R were administered to verify the average intellectual level of the groups.

For the behavioral task 75 ms tones, separated by either 10, 75, 150, 300 or 500 ms, were presented in sequence. The tonal pattern was either 750 Hz then 1250 Hz, or 1250 Hz then 750 Hz.

For the MERP's 10 ms tones, separated by either 75, 150, or 500 ms ISI's, were presented in sequence using the same frequencies as the behavioral task. The inter-pair-interval for all phases of the experiment was 2000 milliseconds. All tones were presented at 45 dB sensation level.

All recordings were taken from Fz and referenced to A1 and A2, with the ground electrode placed at Fpz (10-20 system). Electrode impedance was always below 10,000 Ohms. Activity in excess of 50 *m*v was automatically rejected by the computer prior to averaging. EEG was sampled at 500 Hz for following stimulus onset. A 50 ms recording window was used in the 75 ms ISI condition, and a 100 ms window was used in the 150 ms and 500 ms ISI condition.

MERP's were labeled based on the following windows: No=9-14 ms; Po=12-24 ms; Na=15-39 ms; Pa=25-49 ms; Nb=40-75 ms; and Pb=50-100 ms.

RESULTS

Behavioral Task

The percentage of correct responses to the behavioral task was computed for each subject (see Table 1). Repeated measures analysis of variance revealed a significant main effect for group membership, $F(1,29)=5.78$, $p<.03$, and frequency order, $F(1,29)=17.87$, $p<.0005$. The non-reading delayed group (NRD) was more accurate than the reading delayed group (RD) in identifying stimulus order (M's=78% and 64%, respectively). Both the NRD and the RD group displayed a higher percentage of correct responses for the 1250-750 HZ stimulus order (M=77%) compared to the 750-1250 Hz stimulus order (M=64%), $t(30)=4.06$, $p<.0005$.

Table 1
Percent correct on sequencing of tones during the behavioral task for both reading delayed and non-reading delayed subjects at each inter-stimulus-interval.

	Reading Delayed		Non-reading Delayed	
	Lo-Hi	Hi-Lo	Lo-Hi	Hi-Lo
ISI				
10 ms	56%	63%	80%	83%
75 ms	47%	69%	67%	73%
150 ms	53%	69%	63%	87%
300 ms	53%	81%	73%	83%
500 ms	50%	75%	83%	83%
Mean =	54%	71%	73%	82%

Note: Lo-Hi and Hi-Lo represent the 750-1250 Hz two-tone pattern and the 1250-750z two-tone pattern, respectively.

Event-Related Potentials

Waves No and Po were identified in 72% and 85% of the records, respectively. Repeated Chi-Square analyses revealed that the No peak was present more often in the RD group (80% of the records) compared to the NRD group (64% of the records), X^2 (1, N=279)=9.67, p<.001.

A significant ISI x Group interaction, F(2,25)=3.60, p<.05, was found for the Na-Pa inter-peak latency analysis. A change in mean latency was observed for the RD group but not the NRD group. The RD group displayed a significantly shorter Na-Pa inter-peak latency for the 150 ms ISI (M=9.55 ms) compared to 500 ms ISI (M=12.30 ms), t(13)=3.28, p<.006 (see figures 1, 2 and 3).

A significant ISI x Order x Group interaction, F(2,25)=4.44, p<.03, was observed for the Na component. For the RD group the latency of Na produced by the second stimulus at a 75 ms ISI (M=24.68 ms) was significantly less than the latency at a 150 ms ISI (M=29.11 ms), t(14)=4.66, p<.0005, and at a 500 ms ISI (M=28.93 ms), t(14)=2.87, p<.01. Furthermore, for the RD group at the 500 ms ISI, Na latency to the second tone (M=28.9 ms) was significantly longer than that of the first tone (M=25.9), t(14)=2.80, p<.02.

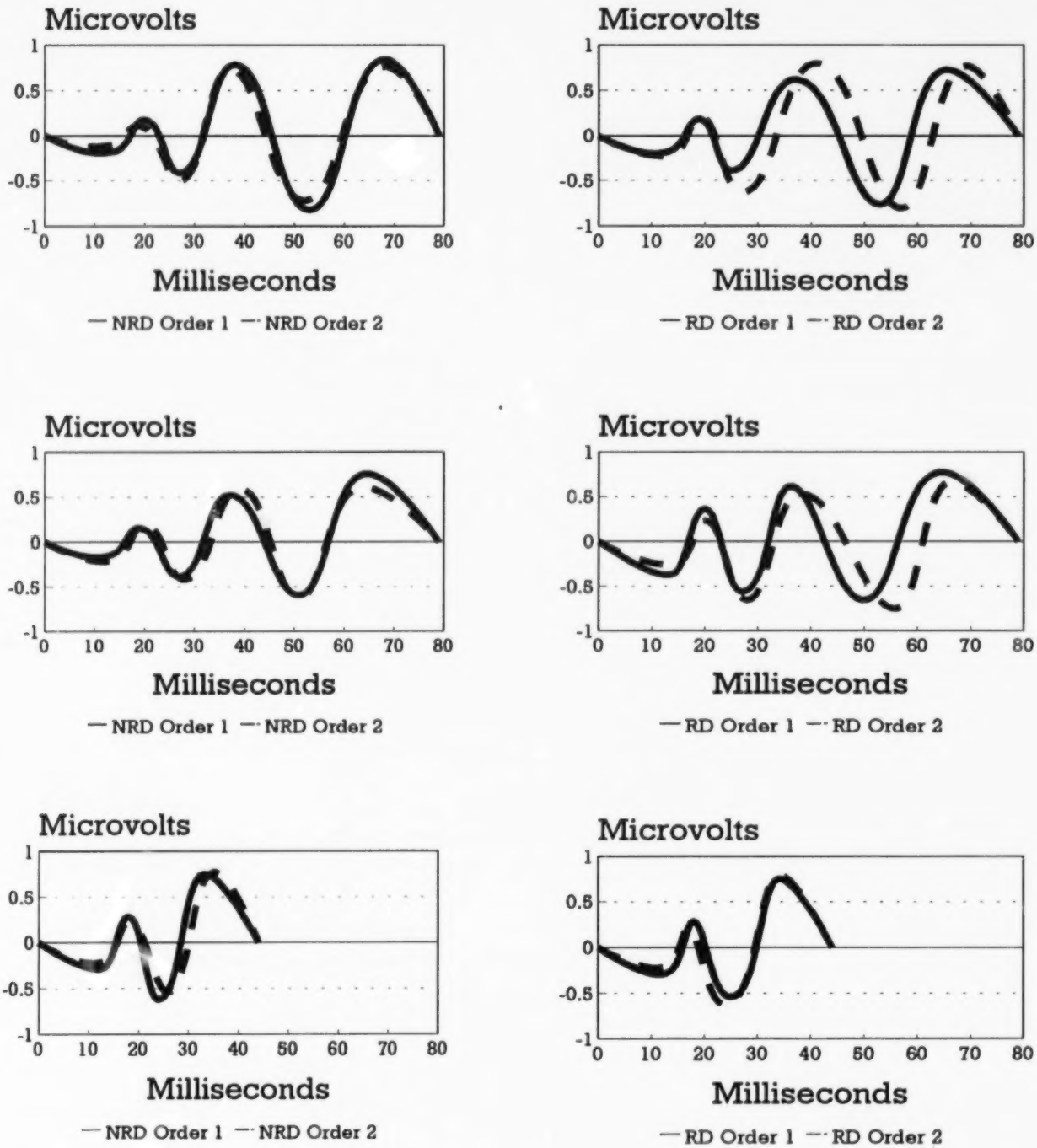

Figure . Schematic representation of middle latency waveforms for both the non-reading delayed (a) and reading delayed (b) groups for the 1st and 2nd order stimulus during the 500 ms (top), 150 ms (middle), and 75 ms (bottom) ISI's.

Behavioral Task Related to Event-Related Potentials

In order to examine the relationship between the subjects' performance on the Behavioral Task and their Event-Related Potentials, a correlation between these measures was conducted. A significant correlation existed between performance on the Behavioral Task and the latency of the Na waveform produced by the stimulus in the second order position. The latency of Na for the second stimulus at an ISI of 75 ms was significantly related to performance on the 10 ms ISI Behavioral Task, $r(31)=.45$, $p<.006$, as well as the 75 ms ISI Behavioral Task, $r(31)=.37$, $p<.03$. The Na latency for the second stimulus at a 150 ms ISI was correlated to performance on the 150 ms ISI Behavioral Task, $r(31)=.35$, $p<.03$. Similarly, the Na latency for the second stimulus at a 500 ms ISI was related to performance on the 500 ms ISI Behavioral Task, $r(30)=.35$, $p<.03$.

DISCUSSION

It appears that in the RD group a lack of inhibition of the second tone at the shortest ISI was present. The RD group displayed a shorter latency for the Na component to the second stimulus at a 75 ms ISI than they did to the second stimulus at 150 ms or 500 ms ISI's.

Thus, the RD group appeared to be increasing processing speed of the second stimulus at short ISI's. At the 150 ms and 500 ms ISI's the RD group responded to both stimuli in a fashion comparable to that of the NRD group. In the RD group at a 75 ms ISI the latency of Na to the first stimulus was greater than that to the second, whereas at 150 ms and 500 ms ISI's the latency of the first stimulus was shorter than the second. Thus, a complete reversal was achieved. For the NRD group the latency of Na for the first stimulus was shorter than the latency for the second at 75 ms, 150 ms, and 500 ms ISI's.

This increased processing speed to the second stimulus at short ISI's could signify a lack of gating or inhibition, possibly due to impaired functioning in the frontal lobe. Knight et al. (1989) reported the amplitude of the Pa wave to be enhanced in the patients with the prefrontal lesions. Furthermore, although not statistically significant at their critical alpha level, the patients displayed a trend for a shortened Na latency as well.

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